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Blood traceability system for Indonesian blood supply chain

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Abstract

The availability of blood bags, adequate quality and quick distribution factor are critical factors in serving demands of blood bags in Indonesia. Indonesian Red Cross Society (Palang Merah Indonesia/PMI) as the holder of the authority to manage the blood bags from the supply of donors until distribution to the hospitals. Many experts believe that the blood traceability system has capability to increase the availability of blood bags and satisfy the quality of blood bags. The objective of this paper is to design the smart blood traceability system to integrate blood bags operations from the major actors in Indonesian blood supply chain. The Architecture of Indonesian blood traceability system has been made with regard to the entire supply chain actors follows the needs and the existing processes. Barcode technology is used to support the data entry of smart blood traceability system. The coding of blood products and shipping has been created using Barcode tags. The smart blood traceability system model was designed using the use case diagram, class diagram and others diagrams in UML approach. The Bloodtrace software was developed and was conducted the try out in one PMI regions in Jawa Timur.

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Keywords: Blood traceability system; blood supply chain; auto_ID technology.

1. Introduction

The Blood bags are a unique perishable products and not ordinary products. Life time of the blood bags product is 21 days and are categorized as a perishable products [1]. The Blood bags aren't produced like manufacturing

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perspective because blood's supply from donors need the willingness and require a period of time to taken again (at least 3 months). [1] pointed out that the characteristics of the blood bags products are the their demands are stochastics and the supply of donor is irregular. In ASEAN countries (e.g., Malaysia and Singapore), their governments given the authority for National Red Cross to manage the blood bags from donors until are transfused to patients in hospitals. The Indonesian Red Cross Society (Palang Merah Indonesia/PMI) is an organization has mandate from Ministry of Indonesian Health as an official institution to manage and distribute the bloods bags in Indonesia.

In managing the blood bags by National Red Cross, the human errors problems are still frequently happen in some activities of supply chain players (donor, national Red Cross, and hospitals). [2] pointed out that the biggest risks to recipients of blood transfusion is human error besides incorrect the blood components and errors in medication administration. In Indonesia, the unavailability of blood bags is critical problems that was solving with Indonesian Red Cross. [3] reported that they often found one district were experiencing a shortage of blood bags but in other districts there have still blood bags stocks. Delays in delivery of blood bags to hospitals who need blood is also still happen. The coordination and integration using an information system can reduce the existing problems in managing Indonesian blood supply chain. Indonesian Red Cross as main players in the blood supply chain need a new information system that has capability to integrate all players in the blood supply chain from taken blood of donor until distribute blood bags products to hospitals.

Blood traceability system is a type of the information system that is able to manage and track the blood bags in the blood supply chain players. The National Red Cross in several countries such as Malaysia, Singapore and Thailand have implemented the blood traceability system. [4] and [5] believed that the benefits of blood traceability system are to (1) reduce human error, (2) improve monitoring of blood bags, (3) improve the safety of patients and medical staff and (4) improve the efficiency of the management of blood bags.

The smart blood traceability system is a types of blood traceability system that has web-base (online) platform and is supported with the automation identification (auto-ID) technology such as barcodes and radio frequency identification (RFID). RFID technology has more benefit and wider application than barcode technology in healthcare [6, 7]. RFID application could be implemented in healthcare such as newborn, patients in emergency and surgery operation room, medical staff, blood bags, medicine drugs, medical records, medical equipment, and others assets [8,9]. Some advantages of the smart blood traceability compared with blood traceability system manual such as (1) is an integrated capable of data for the entire supply chain actors with diverse location/distance, (2) the accuracy of data input to the data donors, blood bags and shipping, and (3) easier to trace and monitor the blood bags products. The auto-ID technology will support the accuracy of data input and real time condition also could be reached. The selection of appropriate auto-ID technologies is to pay attention for the accuracy of entry data and the cost factors. The appropriate auto-ID technology that is used to the smart blood traceability system is stages in design of blood traceability system that should be conducted by manager/ project leader.

Designing software for blood traceability system is relatively complex. Many players/users, activities, types and the amount of information that should be managed in using blood traceability software. In Indonesia context, Indonesian Red Cross (Palang Merah Indonesia/PMI) is the main players in Indonesian blood supply chain. Some activities in internal PMI are needed from receiving the blood bags from donors until deliver to hospitals. The individual and groups donors, blood bank in hospitals, hospital (without blood bank) and PMI other regions are also the players in Indonesian blood supply chain. Various of information in blood traceability system that should collected, shared and analyzed among players in the blood supply chain such as type of blood (0, A, B, AB), rhesus (negative and positive), free of diseases (e.g., HIV, syphilis, and others), blood bags products (e.g., hemoglobin, platelets) and others information every day. As we know, a previous research is limited investigate the benefits and implication of blood traceability system implementation in each players of blood supply chain.

In existing condition, a few PMI regions such as PMI Surabaya and Sidoarjo have the blood information systems. The capability of their blood information system do not integrate among players in blood supply chain. The smart blood traceability system as part of the blood information system that has the ability to integrate among players in blood supply chain. This system should be used by Palang Merah Indonesia to enhance their blood information system. The purpose of this study to design and develop the smart blood traceability system as part of the blood information system for Indonesian blood supply chain. The expected of this study is to increase the capability of PMI and Indonesian hospitals in order blood safety and operations more efficient and effective.

2. The Smart Blood Traceability System Model

2.1. Structure of Indonesian Blood Supply Chain

In this study, the structure of Indonesian blood supply chain was developed to understand the players and users in the smart blood traceability system model (see fig.1). The observations and interviews were used to identify players and users in each players that are showed in the structure of Indonesian blood supply chain. The respondents of this study are (1) two donors, (2) two head of information system in two PMI regions, (3) one head of the blood bank in hospital. Indonesian Red Cross (PMI) is main players in Indonesian blood supply chain. Donors are players that are identical to "the blood supplier". They are a voluntary who donate blood then donor's blood stored in blood bags. The blood bags from donor are processed into "final products" such as whole blood, plasma, thrombocyte and others by PMI. "The final blood products" are distributed by PMI regions produced to hospitals and PMI other regions needed. Two scopes of traceability system (internal and external) should be fulfilled to develop the model of smart blood traceability system for Indonesian blood supply chain. Scope of internal traceability occur in PMI's activities and external traceability occur in the supply of donor and the distribution to the hospitals.

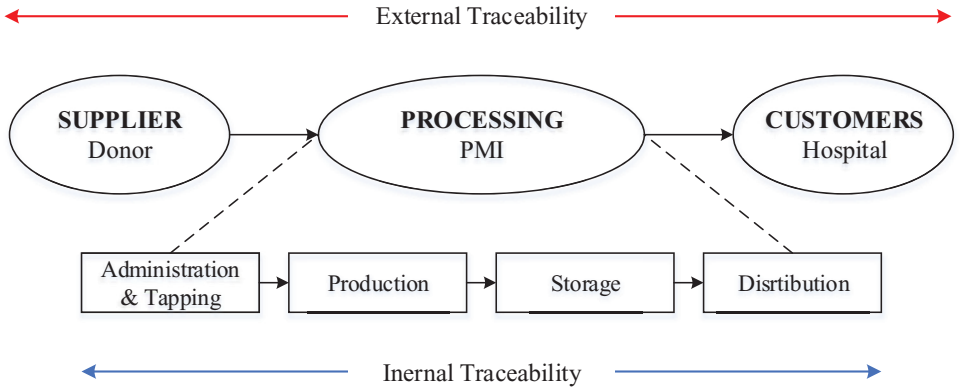


Fig. 1. The generic structure of Indonesian blood supply chain

2.2. The Architecture of Indonesian Blood Traceability System

The architecture of Indonesian blood traceability system is shown in fig. 2. It is divided into two main systems such as the blood traceability system and database server. The blood traceability system is main system and it is created as the set of application layers such as (1) auto-id layer, (2) bloodtrace layer, (3) model layer and (4) function layer. Database server as second system that serve the blood traceability database in the server. The first layer comprises of automation identification (auto-ID) technology is used to capture data as entry data to system using the barcode tags (EAN types). The second layer is blood trace software layer was developed to support the blood traceability system using open sources cross-platform development. The third layer is model layer that consist two models such as blood quality and process and blood inventory and distribution model. The information needed are created by the system in order to support the blood traceability model. Information are resulted such as (1) type of blood and others, (2) when processes each stage get started and finished, (3) what quality of blood required and (4) when the products is received, distributed and shipped. For inventory model, how many the blood bags from donor and the blood products produced still exist. Finally, the function layer is used to provide donor, PMI and inventory information that should be collected, shared, and analyzed.

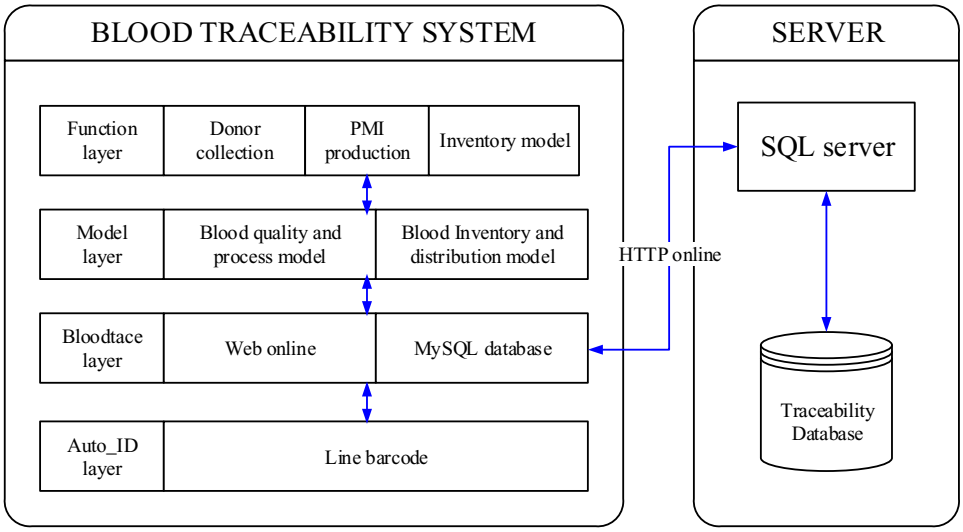


Fig. 2. Architecture of the smart blood traceability system

3. Design for Bloodtrace Software

3.1. The Use Case Diagram

Software of the smart blood traceability system is named the Bloodtrace software. UML approach was used to design blood traceability system and its software using some diagrams such as (1) the use case diagram, (2) the class diagram, and (3) the sequence diagram. The use case diagram as one of diagram in UML approach is a useful approach to capture operation flows and requirements of system functions [10]. Reference [11] also believed that the main advantage of use case analysis is that it helps manage the complexity of systems. Usage of UML approach to design traceability system in agriculture and manufacturing sectors quite a lot such as [12] and [13]. The use case diagrams are closely connected between actors and systems (the use case and system boundary). In this paper, we are shown the use case diagram for blood traceability system in fig. 3. Each case in systems is defined as follows:

- *Administration and blood tapping*: administrative officer and doctor in tapping unit responsible for all activities in this process. Registration process for new donors is a first activity that is served by the administrative officer. As for donors who have registered will be continued by the registration of tapping process. The officer can trace the record's donor such as the previous results of blood test using tracking menu in Bloodtrace software. PMI's doctor conducts a medical examination of a donors such as the blood pressure test and the blood type test). The blood tapping process will be carried out if the results medical examination meet requirements.
- *Production*. The main objective of this process are to product types of blood products such as whole blood, plasma, fresh plasma, thrombocyte, washed red cell and anti-hemophilic factor concentrate. Some department in PMI such as "AFTAP", "IMLTD" and production department have a responsibility to product the blood products that are needed by hospitals. In AFTAP department, the staff creates the receiving invoice in order to inform the donor's blood bags ready to be produced. IMLTD staff conduct strain testing and production staff produce some blood components as "final blood products". Labeling process will be conducted to tag each blood component products.
- *Storage.* Donor's blood bags are temporary cold storage before production process are conducted. The FIFO system is used to regulate the blood products that should come out first in cold storage.
- *Distribution.* Based on order from hospitals and PMI other regions, PMI's distribution staff distributes the blood product ordered. PMI's distribution staff ships the blood products to blood bank in hospitals. Besides that, the staff of hospital directly take the blood products needed in PMI.

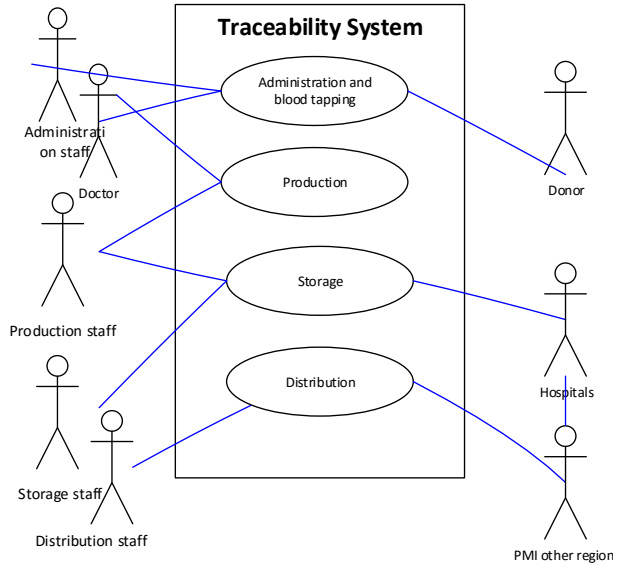
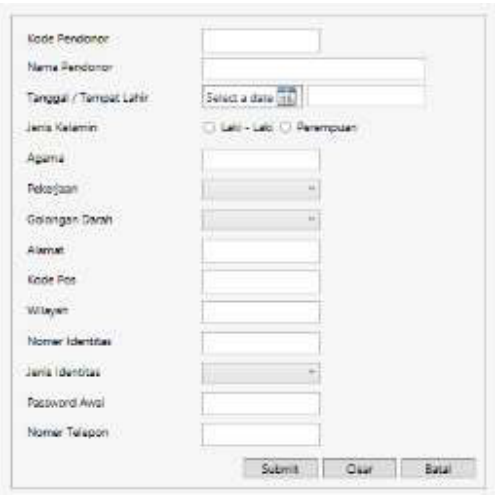


Fig. 3. The use case diagram for blood traceability system

3.2. The Bloodtrace Software

Based on design of smart blood traceability system, Bloodtrace as new traceability software was developed by open source cross-platform development. With open source development, the functions of blood traceability system were implemented in some modules such as administration and tapping, production, storage and distribution module. In fig. 4, the interfaces of Bloodtrace software especially main menu and donor registration process were shown.

(a) Main menu



(b) donor interface

Jenis Komponen	FULL KODE	ID Donor	Jenis	Waktu Periksa	HIV	Sifilis	Hepatitis	HCV
Whole Blood	1031302818001	10327019500001	Triple	5/25/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Whole Blood	1031301391001	10327019500002	Triple	5/26/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Whole Blood	1031301715001	10327019500003	Triple	5/27/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Whole Blood	1031301429001	10327019500004	Triple	5/28/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Whole Blood	1031302269001	10327019500005	Triple	5/29/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Pack Red Cell	1031574564002	10327019500006	Triple	5/30/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Pack Red Cell	1031574564002	10327019500007	Triple	5/31/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Pack Red Cell	1031574695002	10327019500008	Triple	6/1/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Pack Red Cell	1031575017002	10327019500009	Triple	6/2/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Pack Red Cell	1031574106002	10327019500010	Triple	6/3/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif
Pack Red Cell	1031575329002	10327019500011	Triple	6/4/2015	Non Reaktif	Non Reaktif	Non Reaktif	Non Reaktif

(c) example of blood test records)

Fig. 4. Interface in Bloodtrace software (a) main menu (b) donor interface and (c) example of blood test records

4. Results and Discussion

Bloodtrace software for blood traceability system was developed. In order to understand the beneficial of software for each players in Indonesian blood traceability system, the validation of bloodtrace software was conducted. Some benefits were identified using review papers related. Based on interview with some persons as donors, head of information system in PMI and hospital, some benefit that can be contributed by bloodtrace were founded. The benefits that can be reached are (1) reducing human error, (2) increasing monitoring process (e.g., expire date of blood bags), (3) increasing the information sharing among players of blood supply chain, and (4) reducing operational costs. Table 1 shows some benefits of blood traceability system each players.

Table 1. The benefits for players of blood supply chain

Benefits	Donors	PMI	Hospitals
Reducing human error	None	Human error could be reduced with the discipline of staff using Bloodtrace	human error quite could be reduced
Improving monitoring process	None	Monitoring process could be increased particularly blood records and the availability of blood bags	Monitoring could be increased particularly availability of blood bags
Increasing information sharing	Understand their health medical and and blood record history	Information sharing with the hospitals and the PMI other regions is easier implemented	information sharing with PMI more easily implemented
Reducing operational costs	None	Operational costs could be reduced	Operational costs could be enough reduced particularly telephone, fax billing, etc.

PMI and hospitals are the players of Indonesian blood supply chain who get more some benefits than donors. Donors only helped with the blood traceability system to determine their medical history. The disciplines of PMI and hospitals staffs to use Bloodtrace software is one of the important factors that attempt to reduce human error. The efforts to monitor the condition can also be improved, especially the blood of the donor if it is the result of a positive blood test indicated disease. The ability to monitor all processes can also be improved, especially the condition of the blood donor if the results of their blood tests for diseases are positive. Problem of blood expired is a few in PMI case because the amount of demand from the hospital are relatively same. Duration of blood stocks are also quite short.

The sharing information between hospitals could be improved, especially the hospitals that have blood banks. The hospital needed a blood bags as the stock in order to fulfil hospital's demands more quickly. The respondents also believed that some items costs can be reduced such as fax and telephone costs. In addition, the productivities

for employees can also be slightly increased using the blood traceability system.

The hospital convinced that the blood traceability system has ability to reduce human error. The events of human error in the PMI are also effect to the hospitals and patient's hospitals. The correctness and completeness of information for the blood bags is an important factor to reduce human error in hospitals. The availability of blood bags can be detected by the hospital using the tracking menu in Bloodtrace software. The sharing information among players in blood supply chain is easy to be reached. The advantages of Bloodtrace software that web-based platform is a connection and integration between PMI and hospitals in difference locations could be released. The operational costs especially communication and transportation costs also could be reduced.

5. Conclusions

The Bloodtrace as a blood traceability system software was developed for Indonesian blood supply chain. The ability of Bloodtrace software is able to integrate the sharing information and coordination among the blood supply chain players that couldn't realize by the existing blood information system. The slightly contributions of this study is develop the blood traceability model and software as a new the blood information system.

The benefits of the Bloodtrace were gained for all players in blood supply chain. The PMI and hospital players believed that Bloodtrace software is needed by PMI and hospitals in order to improve the existing blood information system. The hospitals that have blood bank unit more benefits compared with hospital that have not the blood bank unit in their hospitals. The donor players are least gain than PMI and hospitals. The implication of this research such as the socialization of Bloodtrace application is also needed in order users in PMI and hospitals players to understand how the Blodtrace software is successfully implemented. Discipline and IT knowledge of staff/users as critical factors in implementation in each players should be increased. The smart blood traceability system need the policy and effort to achieve the success of Bloodtrace implementation. Firstly, the cooperation among PMI and hospital to use Bloodtrace software as new platform for their information system should be agreed. Secondly, the training for staffs of PMI and blood bank in hospitals are needed to increase the staff's knowledge and skills for Bloodtrace software.

For future study, firstly, the benefit cost analysis is necessary used to ensure whether the benefits of Bloodtrace software obtained is greater than its costs incurred. Secondly, the longitudinal case study of the Bloodtrace implementation are needed in order to investigate the implications for each player and of blood supply chain. What are the appropriate quantitative indicators is critical research questions in order to justify the success or fail of the Bloodtrace implementation. Finally, longitudinal study is also suggested in order to understand beneficial, critical success factors, and barriers of Bloodtrace implication of each players with 3-5 years durations.

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